SECONDARY NERVE SUTURE.[1]

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IT has long been known that divided nerves would, under certain favorable conditions, unite, with restoration, more or less complete, of the functions which had been abrogated by the injury. Indeed, this fact has played a prominent part in the results of the operations which have been performed on nerves, the seats of neuralgia, where it has been sought to cure the pain by abolishing the sensibility of the affected nerve, by separating it by section from its trophic centre. These operations, as is well known, though giving temporary relief, have commonly failed to be of permanent benefit, because the divided nerves after a certain lapse of time have reunited, with re-establishment of function which has announced itself by a return of the pain in all its original severity. To avoid this disappointing result, operators have been at much pains to prevent, if possible, the reunion of the divided trunk, and various devices have been resorted to for this purpose. Sometimes considerable portions of the nerve have been removed, sometimes a loop of the exsected nerve has been doubled back at each cut extremity, and some have fastened back these loops by sutures or ligatures. Some have modified this procedure, where the trunk was easily accessible, by burying the looped ends deeply in the surrounding tissues, and sometimes foreign bodies have been interposed between the divided ends to keep them separate until the disposition to unite should disappear. In spite of all these precautions, it

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has not been possible, in certain cases, to prevent a recurrence of the neuralgic disorder,—a recurrence which is generally believed, and in some instances has been proved, to be associated with a union, and sometimes with an extensive regeneration, of the injured nerve. Examination of nerve-trunks which have undergone this regeneration have shown the nerve-tubules perfectly restored in their continuity, and but little changed in their normal condition.

Such facts as these led very naturally to the hope that nerves, accidentally divided, and where restoration of function has not occurred, might be restored to their normal powers of transmitting sensory and motor impressions by exposing the injured trunk and bringing together by suture the divided ends. This operation is not by any means a new one. It was done by Arnemann in 1826, and by Flourens in 1828, and it is stated that it was practiced by Dupuytren, in several instances, at the Hôtel Dieu. It was not, however, until after the elaborate researches of Augustus Waller, which were published in the *Comptes rendus* of the Academy of Sciences in Paris, in the year 1852, that the operation was placed on a scientific basis. He showed, by means of experiments on animals, the whole history of degeneration and regeneration of nerves after injury so completely that he has left scarcely anything to be done by his successors, and, encouraged and guided by his discoveries, surgeons have performed the operation of the suture of divided nerves in a large number of cases in England, on the continent, and in this country, with a success generally extremely satisfactory, though it must be acknowledged not equally or uniformly so. The operation has been done in certain instances immediately on the receipt of the injury, while the cut surfaces were yet fresh; and it has been done as a secondary operation, weeks, months, and even years after the original accident, thus dividing the operations into two classes, the primary and the secondary. It is of the latter only, the secondary operations, that I propose to speak this evening.

I have had the opportunity of performing the operation in two cases, of which the histories are as follows:

Valentine Keller, a German, aged thirty-six, was brought into the New York Hospital, December 25, 1883, with a stab wound of the

left arm. The wound was situated on the external aspect of the arm, about two inches above the external condyle of the humerus. It was not more than half an inch long, but the blade of the instrument had penetrated so far as nearly to transfix the limb, grazing in its course the anterior face of the bone. It was noticed that there was no pulsation at the wrist. A counter-opening was made at the point where the wound approached the skin on the inner side of the arm, and a fenestrated drainage-tube passed from one opening to the other. The day after his admission, without any apparent cause, a profuse arterial hæmorrhage took place. The wound on the inside was enlarged, and the brachial artery tied above and below the wounded point. No further hæmorrhage occurred, but the loss of blood had been so great as to bring on a condition of collapse which was very alarming. Transfusion with a saline fluid was promptly resorted to, and gradually the patient rallied. The wound healed slowly, mainly by granulation, and cicatrization was not complete till the end of January. On the 20th of January attention was called to the fact that paralysis, both of sensasation and motion, existed in the parts supplied by the musculo-spiral nerve. There was loss of the power of extension of the hand; flexion of the hand not impaired. There was loss of extension of the fingers, flexion remaining perfect, motions at elbow joint perfect. Anæsthesia, but not complete, existed over dorsal surface of thumb, index and middle fingers, with a good deal of burning pain. He had now recovered his general health, but no improvement could be discovered in the paralyzed parts, though electricity and massage were daily and faithfully employed. He suffered so much from the causalgia, and the trophic disturbances in the muscles and skin were beginning to show themselves so distinctly, that suture of the nerve was decided upon, and performed on the 9th of February; forty-six days after the receipt of the wound.

An incision was made along the course of the musculo-spiral nerve, having the scar of the wound as its centre. A good deal of cicatricial tissue was encountered in passing down between the brachialis anticus and the supinator longus, but, when the nerve was reached, it was found to be free and distinct above and below the point of injury; and was, without much difficulty, isolated from the cicatricial mass and cut off clean with a pair of sharp scissors. By flexing the arm the divided ends could be easily brought together, and the two were united by two slender catgut sutures passing through the substance of the nerve. The signs of degeneration of either end were not distinct. The wound was carefully closed and the forearm left flexed at about a right angle with the arm.

February 10th.—Complains of much pain in the wound, but says he feels it radiating down the limb, along the musculo-spiral distribution, mostly on the dorsum of the thumb and the index finger. This pain was regarded as a favorable sign, and, it was hoped, would be the precursor of rapid restoration of lost power. This expectation, however, was not realized. The pain gradually subsided, and then disappeared altogether, the wound meanwhile healing well, mostly by primary union. By the time the operation was performed the man had recovered his health and strength, and seemed to be in as good a condition as could be desired for its success. Electricity and massage were employed daily, and he was encouraged to use the arm as much as possible. The faradaic current caused no response. The galvanic produced at first some contraction, but this soon ceased entirely. The affected muscles were flabby, but not appreciably atrophied. He was kept under observation, and treatment was sedulously continued, when, on the 14th of April, at his own request, he was discharged from the hospital. At this time there was no apparent improvement in the condition of the paralyzed muscles. The conditions as to sensibility were not noted. The hand and fingers were perfectly powerless so far as extension was concerned, and the member was therefore practically useless. I explained to him that restoration of function was often long delayed in these cases, and encouraged him to use all the muscles of the limb that were capable of acting, and in particular I urged him constantly to direct his will along the paralyzed cord and try to make the muscles respond to their natural stimulus. I heard nothing more from him except that he was under Dr. McBride's care in the out-patient department of the hospital, and was not improving. Recently, however, I have received a note from Dr. McBride saying that Dr. S. O. Van der Poel, Jr., who had acted in his absence, had reported to him that the man had so far recovered the use of the limb as to be able to go to work.

I saw him on the 1st of February, and found that he had regained the use of the paralyzed muscles so far that he could extend the hand and fingers, and supinate the hand almost to the full extent, and with a good deal of power. The actions could not be performed rapidly as yet, nor completely, owing, no doubt, to the stiffness of the joints concerned from prolonged disuse. He is conscious of daily improvement, both in strength and facility of movement. The muscles can be felt to contract under the finger, and have regained their normal bulk and firmness.

The second case was to me one of unusual interest, as I had no experience, either of my own or of others, to guide me in

diagnosis, prognosis, or treatment. I believe the case to be unique in the history of surgery.

Lillie Dougherty, aged five years, was admitted to the New York Hospital, Oct. 22, 1884, with a wound of the neck, inflicted by a sharp, clean instrument, a short time before her admission. There was found an irregular wound, extending from the nucha on the left side, opposite the fourth cervical vertebra, passing obliquely downward and forward to the posterior border of the sterno-cleido-mastoid muscle, and stopping about an inch above the upper margin of the clavicle. The sterno-mastoid and the trapezius were both partly divided. Considerable hæmorrhage had occurred, but no vessel required a ligature. The child was slender in form, pale and delicate in appearance, but in good health, as far as could be ascertained. The wound was brought together carefully, treated antiseptically, and healed, partly by granulation, in about a month. Soon after the injury, October 30th, it was noticed that she was unable to raise the right arm from the side, and gradually, as the disability of the shoulder from the wound subsided, it became evident that a certain amount of paralysis existed, unquestionably dependent upon some nerve injury inflicted in the depth of the wound. There was no nerve-trunk in the course of the wound whose division could account for the paralysis, and in point of fact nothing but a wound of some part of the brachial plexus was competent to explain the symptoms presented, and this idea was rejected by me at first, and for two reasons: First, the wound did not appear deep enough to reach any part of the brachial plexus, and, second, the line of incision in the neck seemed to be entirely above the course of the fifth cervical nerve, which forms the uppermost cord of the plexus. On carefully studying the conditions, however, I finally reached a positive diagnosis, becoming convinced that nothing could have happened in such a wound, except a severing of the upper cord of the brachial plexus, which could afford an explanation of the symptoms presented.

These symptoms were loss of power of abduction of the arm and of flexion of the forearm upon the arm. Supination was limited and feeble; pronation good; extension of the forearm slightly, if at all, affected. Flexion and extension of the hand and fingers were not notably impaired. Anæsthesia was well marked over the shoulder and the outer aspect of the arm. By the time that cicatrization of the wound had taken place, about the 1st of December, these signs of paralysis had become perfectly distinct, and it was also noted that atrophy was beginning, and was, in fact, well marked in the deltoid, and supra and infra-spinatus muscles, and less distinctly in the biceps and brachialis anticus.

She was placed upon tonic and invigorating treatment and regimen,

and everything was done to improve and maintain her general health. Faradization of the affected muscles and friction of the shoulder and arm were continued daily, without any manifest results. The general condition improved very much to our satisfaction. She was very tractable and obedient in seconding our efforts to make her use her arm and shoulder muscles, as far as her will had any control over them. No improvement could be discovered, the arm hung useless by her side, and, when she wanted to play with her dolls, she had to lift the palsied arm on to her lap with the other hand, and then she could use the fingers to hold it.

On the 8th of December a careful examination of the reaction under galvanic and faradaic currents, was made, with the following results:

MUSCLES OF THE SHOULDER.

Nerve.	*Muscle.*	*Galvanic Current.*	*Faradaic Current.*
Spinal accessory.	Sterno-mastoid, trapezius.	Normal.	Normal, m. and n.
Anterior thoracic.	Pectoral.	Normal.	Normal.
Subscapular.	Latissimus dorsi.	Normal.	Normal.
Circumflex.	Deltoid.	Normal; increased when applied to muscle direct (reaction of degeneration).	Absent; muscle atrophied.

MUSCLES OF THE ARM.

Nerve.	*Muscle.*	*Galvanic Current.*	*Faradaic Current.*
Musculo-cutaneous.	Biceps, brachialis anticus.	Normal; increased when applied to muscle direct (reaction of degeneration).	Absent, m. and n.; atrophy of muscles.
Musculo-spiral.	Triceps, supinator longus.	Normal.	Normal, or slightly diminished.

The reaction of the muscles supplied by the rhomboid, suprascapular, and long thoracic nerves could not be satisfactorily obtained, but the muscles themselves showed marked atrophy. The muscles of the forearm were not involved.

The faradaic current was now replaced by the galvanic, which was applied daily. No improvement in muscular reaction. Atrophy of shoulder muscles appears more marked. Her general condition is greatly improved. She is in good spirits, eats and sleeps well, and presents the appearance and demeanor of a child in good health.

That the most careful study of the paralyzed muscles alone would have warranted a diagnosis as to the precise point of injury, I am not prepared to assert. Taking, however, all the points as they have been

presented above, and associating them with a careful topographical survey of the line of the wound, and there seemed to be but one conclusion to which all the facts pointed, and that conclusion marked the fifth cervical nerve, which is the first or upper cord of the brachial plexus, as the seat of the injury, and, in consultation with my colleagues, it was deemed right to make an attempt to suture the wounded cord, in the hope of restoring the functions of a limb in its present condition absolutely useless. In view of the fact, however, that these injuries to nerve-trunks do sometimes recover spontaneously, it was thought best to wait, before undertaking any operation, until it should become quite certain that nature was unable to effect a cure. Accordingly, treatment was steadily persevered with until the beginning of March, when, no improvement being perceptible, it was deemed justifiable to try what surgery could do to bring relief.

The operation was done March 2, 1884, one hundred and thirty-one days after the infliction of the wound. An incision was made along a line corresponding to the upper part and outer margin of the brachial plexus, and carefully followed down until this border of the plexus was reached. The cicatricial tissue was very extensive, and very confusing as we tried to recognize the anatomical landmarks, and a very careful and tedious dissection was necessary before we clearly recognized the nerve-cord involved in the wound. Finally, however, the nerve-trunk above and below the wound could be distinctly seen, and was isolated sufficiently to enable us to trace its whole length from the point of its emergence from the intervertebral foramen to the point where it joins the plexus below.

We were extremely careful not to handle roughly, nor to pinch with forceps, any part of the exposed nerve, and this it was that so greatly prolonged an already very tedious operation. The cord, which was now seen to be the upper root of the plexus, as we had originally supposed, was divided in two places with sharp scissors, so as to include all that part involved in the cicatrix, leaving a clear cut on both distal and proximal ends through healthy nerve-substance. I say healthy nerve-substance, but it became evident, on making the section, what I suspected when the nerve was first exposed, that the distal portion beyond the cut was in a condition of physiological integrity, while the short portion, less than an inch in length, which formed the proximal stump, was manifestly smaller, its fibers not so clean and glistening as in the cord below and in the surrounding nervous trunks. In short, it was the proximal, and not the distal portion of the cut nerve which had undergone the classical degeneration, the distal portion retaining almost perfectly its normal appearance. I very much regret that I can not

make this statement with the authority which would give it value as a scientific fact; for, unfortunately, no microscopic examination of the cut ends was made, and I am well aware that the gross appearances, though very distinct, would not alone be reliable evidence as to the condition of the nerve-tubules. Two very fine catgut sutures were now passed through the cut ends and tied not very tightly. Some strain on the suture was easily overcome by flexing the head on the trunk, and drawing it toward the left side. In this position it was secured by bandages. The wound was dressed with iodoform and sublimate gauze, and behaved perfectly well, though not healing entirely by primary adhesion. By the 14th of March the wound was cicatrized, and she soon regained her usual condition of health. Convalescence was delayed by a pretty threatening attack of purulent conjunctivitis, which at one time seriously threatened the cornea. This, however, passed safely by, with no corneal damage, and no further complication occurred. The electrical treatment was resumed, and continued during the remainder of her stay in the hospital. No improvement followed the operation, and at the time of her discharge, in the beginning of May, the condition of the muscles, both with regard to electrical reaction and voluntary motion, was just what it had been before the operation, saving that the atrophy, particularly of the deltoid, was more than ever conspicuous.

During the summer she was taken to the country, and seemed in all respects quite well, but no change in the paralyzed parts was noticed until about the 1st of October, when slight voluntary motion began to show itself, which slowly but steadily improved. About the middle of January she was brought to my office, and I was delighted to find that she could flex the forearm upon the hand, and could abduct the arm from the side, during which movements the muscles could be felt contracting and hardening under the finger placed upon them. The shoulder had recovered its rounded contour, and the flexor muscles had become markedly developed. In short, the evidences of atrophy had disappeared, and the indications of voluntary power were daily increasing. On the 21st of February I saw her again, and found the extent and power of muscular motion surprisingly increased. The case promises to prove a complete success.

The study of this whole subject during the last fifty years has led to some important and very interesting discoveries as to the behavior of nerves under and after severe injury. In the first place, it has been shown that, after complete section of a nerve-trunk, there ensues a degeneration of all of that

part of the nerve beyond the point of severance, which extends throughout the whole distribution of the cut nerve, and is so complete that, according to most observers, all trace of original nerve-tissue is lost. There is, however, considerable discrepancy of opinion as to the completeness of this destruction, some contending that it is absolute and entire, others believing that the sheaths of Schwann and the axis-cylinder never entirely disappear. That nerves thus degenerated after section was known long before his time, but Augustus Waller, in 1852, by his admirable and ingenious experiments, brought out all the facts connected with both the degeneration and regeneration of nerves so completely that scarcely anything of importance has been added to the history of the process since his time. The changes, as described by Ranvier, are about as follows: The experiments being conducted on cats and dogs, it was found that after section of a nerve the distal segment began to show signs of change as early as the first day. The myelin begins to disintegrate, and by the fourth to the sixth day has mainly disappeared, leaving the sheaths of Schwann filled with fine, fatty granules. The axis-cylinder has also, by this time, according to his observations, entirely disappeared. By the twentieth day the sheaths of Schwann have become empty, and this he considers to mark the extreme point of degeneration, from this condition very little change being observed. A similar degeneration is noticed to begin at the cut extremity of the proximal end, but only reaches for a line or two from the end of the nerve, and then ceases, the axis-cylinder remaining unchanged. This disintegration is now to be followed, after a varying interval, by a regeneration, by which, in favorable circumstances, the altered nerve is to be restored to its normal condition and functions. This change consists in a reversal of the steps which the nerve took in its degeneration. The sheaths of Schwann, which, according to this observer, never entirely disappear, begin again to be filled out with a granular substance, which soon assumes the character of myelin, the axis-cylinder makes its reappearance, and, in short, the atrophied and shrunken cord gradually assumes the appearance, and nearly the dimensions of the original nerve. While this reformation of the nerve-tubules is going on, the union of the

cut ends is being accomplished. By about the twentieth day fine delicate fibers begin to sprout from the proximal end into the cicatricial tissue which surrounds it, and, gradually developing themselves in size and perfection of organization, shoot through the intervening bond of union till they encounter the distal end, with which they amalgamate themselves. Finally, if the ends are in good apposition, the cicatricial bond of union is occupied and displaced by a newly-formed nerve, which joins the two into one continuous cord, in which the individual nerve-fibers are almost perfect imitations, perhaps on a slightly reduced scale, of the original nerve-elements. In the animals experimented on, the repair was not perfected until about six months had elapsed. In man, it is probable that the period of perfect restoration is longer, but no accurate knowledge on this point has been attained.

Another of the effects of nerve-section, which has of late engaged the earnest attention of both physiologists and practical surgeons, is the paralysis of motion and sensation, which usually follows a complete section of a nerve-trunk. I say usually, because the results of nerve-division are by no means uniform or constant. There are reported, for example, a certain number of cases in which, after complete section of a nerve-trunk, no loss of sensibility could be detected in the parts supplied by it, and a certain number of others in which sensibility, being momentarily suspended, has been regained in a period so short as to make the immediate and perfect union of the divided ends the only explanation possible of the rapid restoration of nerve-power. Still further, it is constantly noticed that anæsthesia following a divided nerve-trunk does not by any means accurately correspond with the area of distribution of the branches of that trunk, but is much less extensive than it should be, anatomically speaking, sometimes occupying only a small part of the region, the whole of which we should expect, *a priori*, would be affected. To the explanation of these facts much attention has been given by German and French observers, and much careful research has been expended, with the result of leaving some of the phenomena not as precisely accounted for as might be desirable.

The first mode of explaining these facts of the limited area

of anæsthesia, and the rapid return of sensibility, is by invoking the aid of anastomosis. That anastomosis, in the ordinary acceptation of the term, does not exist among the nerves, is conceded. It has been demonstrated by Waller that the nerve-tubules individually are continuous from the point of their central origin to the point of their final distribution, and that no communication exists between the myelin in these tubules, and that therefore one tubule can not take up the function of a neighboring one which has been injured. It has been clearly shown, however, by the elaborate experiments of Arloing and Tripier, that, in the cat and the dog, and in the horse and the ass, there are certain tubules which pass from one nerve to another in a continuous or in a reverse direction, to be lost on the nerve to which they have attached themselves at a varying distance on the adopted trunk. These intercommunications are found first in the plexuses, where they are probably very frequent. Second, in the branches which are known to pass from one nerve-trunk to another in the course of its distribution, such as those that pass between the median and the radial, and the anastomotic twig that joins the ulnar and the internal cutaneous. The most abundant anastomosis, however, is found near the peripheral termination of the nerves, where all the terminal twigs unite to form the network of final distribution.

Another explanation of the partial and limited anaesthesia which sometimes follows nerve-section is found by some in the belief that there may be such a thing as the immediate union of the divided ends with immediate restoration of function. This belief is entertained by such men as Schiff, Gluck, Tillmans, Paget, and more recently by Caput and Wolberg, who consider that this primary union is so prompt and complete that no degeneration of the distal fibers can take place; while, on the other hand, it is held to be untenable, because unproved, by such observers as Nicaise, Weir Mitchell, Letievant, Brown-Séquard, and indeed by the majority of the most distinguished experimenters. These observations as to the limitations of paralysis after section do not apply quite so commonly to lesions of motility. Here the conditions seem to be somewhat different. The effect of section here seems to be, almost

uniformly, a complete motor paralysis, followed pretty early by muscular atrophy, which continues until the function of the nerve is restored by its union. Letievant has, however, called attention to the fact that even here there is room for deception, the associate muscles not paralyzed acting so as in a measure to supply the deficiency of those that are paralyzed, so as to give to the whole group what he calls supplemental motility, which may easily mislead the careless observer. This error is easily avoided by applying the electrical test and by noting the atrophy which is sure to develop itself soon after the nerve supply is cut off. These electrical tests are exceedingly valuable in all stages of these injuries, and may be furnished by both the faradaic and the galvanic currents, applied either to the cut end of the nerve or to the skin over the belly of the affected muscle. It is noticed that the electrical current, applied in either way, soon after section, causes a feeble contraction of the palsied muscles, but that this contraction grows less and less from day to day, as the muscular fiber is undergoing disorganization, and finally ceases altogether, the strongest current producing no response. A curious fact is observed in connection with these electrical tests. It is thus expressed by Nicaise: "The faradization curve during the first fifteen days becomes gradually depressed. After the third week the muscle is no longer excitable, at least through the skin. Toward the sixth week, in favorable cases, the excitability reappears, and gradually increases until it reaches the normal reaction. The galvanization curve follows an entirely different course. During the first fifteen days it follows the faradization curve; but from the third week, when the interrupted currents have no longer any effect, the galvanic reaction becomes exaggerated, the curve is raised, soon exceeding the normal, and reaches its maximum when the other is at its minimum. At the moment when repair begins to take place, the galvanic phenomena follow an inverse order; at the same time that the faradaic current is raised, the galvanic cuvre is lowered, and both gradually return to the normal level." This is what is spoken of as the reaction of degeneration by the German authors.

With regard to the facts of compensatory nerve-supply, after

section of a trunk, there can be no doubt, as the facts are so common and so easily observed; but as to the part which anastomosis takes in this return of function, our knowledge can hardly be said to have assumed a positive character. For example, the experiment by Arloing and Tripier—in which each of the four nerves going to a toe in the dog's paw were successively divided, with the result that no insensibility to pain followed the division of the first nerve, and none followed the second, and none the third; but when the fourth was cut, complete anæsthesia was immediately produced—seems to indicate so perfect a communication between the different nerves at some part of their course that we can hardly understand why, if this communication is always present, a severed nerve should show any sign whatever of paralysis.

Another point in the anastomotic theory, which at first seems hard to comprehend, has reference to the communicating branches which join together some of the larger trunks. In these there have been shown to be fibers which pass from one trunk to another, recurving toward the cerebral centers, when they reach the trunk to which they are destined, and reaching a certain distance up this trunk toward its point of origin. Now, as far as we know, nerves in their normal condition transmit impressions only in one direction, *i. e.*, the sensory nerves send their current from the periphery to the center, while the motor fibres bring the mandates of the central organ to the muscles at the periphery. If, therefore, there is to be any anastomotic current supplied through these recurrent fibers, the nervous impulse must pass along the nerve in a reverse direction to that which it originally followed. This is a fair objection to this part of the theory, and at first sight seems well taken. The well-known and ingenious experiment of M. Paul Bert I think fully answers the objection. M. Bert made an incision along the back of a rat, and then, having denuded the end of the tail of its skin, placed the tail thus denuded in the incision in the back, where it adhered firmly. After the union had become firm, he cut off the tail at its root, leaving its end adherent to the back. Now, upon irritating the tail at its root, evidences of sensibility to pain were distinctly manifested, showing that a nerve under altered cir-

cumstances could convey impulses in a reversed direction, very much as a telegraph-wire can convey messages in both directions.

Of the *technique* of these operations, but little requires to be said. The injured nerve-trunks are usually superficial, and therefore easily accessible. In the operations which I have done, the main difficulties have been, first, the finding and identifying the atrophied extremity; and, second, the disentangling, without bruising or laceration, of the cut ends from the cicatricial tissue by which they are surrounded, and with which they are apt to be very closely incorporated. Both these proceedings require great delicacy in handling, and great patience in unraveling the slender and fragile fibers, and in extricating them unharmed from the tough and unyielding cicatrix in which they are buried. Another difficulty which I encountered in the neck case was the misleading effect of the cicatricial tissue when I was trying to follow down the areolar interspaces in order to arrive at the injured nerve. So utter was the confusion of layers that, although I had rehearsed the operation many times on the cadaver, I found myself wandering so far from my course that I was well over toward the jugular vein before I could be sure of my landmarks. The two ends of the divided nerve being exposed, the extremity of each is to be severed with a pair of sharp scissors, taking care to go sufficiently high to reach original nerve-tissue, and at the same time being careful to avoid cutting away more than is necessary lest the tension be increased when the ends are brought together. In one of my cases, that of the arm, microscopic examination showed no trace of nerve-fiber in the part cut away by the scissors, proving that my section had not reached the real nerve-end. This I think unfortunate, and must always delay, and probably sometimes defeat, the object of the operation. Various sutures have been used to join the cut ends, but opinion seems to have settled upon catgut, as fine as is consistent with strength. The shape of the needle is not unimportant. A common round cambric-needle is the best, making its way through the tissues by displacement rather than by cutting. Wolberg recommends a flat needle, shaped like a saber but without cutting edge. Some are care-

ful not to pass the needle through the substance of the nerve for fear of injuring the tubules. Most operators prefer to pass the suture through the body of the nerve, as securing a stronger hold. Some cut the two ends obliquely so as to make flaps which, being applied to one another, afford an increased surface of contact. Rawa brings the ends together side by side, and then surrounds them and binds them together with a catgut ligature. When much loss of substance has occurred and the ends can not be made to touch, Vanlear has suggested placing the ends in a Neuber's drainage-tube, and, with catgut threads attached to each end of the nerve, drawing them as near as possible together within the tube, and leaving the space between the ends to be filled up by the reparative material. In a case in which he found it impossible to bring the ends in apposition, Löbker resected the bones of the forearm, thus shortening the limb so that the ends could be approximated without tension. In an experiment, Gluck transferred a rabbit's nerve to the limb of a chicken with success; and on the human subject, Albert replaced an exsected nerve with a segment of nerve taken from a recently amputated limb.

The nerve-ends being brought securely together, great care is to be taken, by position of the limb, that no tension should occur. The wound should be brought together so as to secure primary union, if possible, as the healing by granulation is believed to exercise a very unfavorable influence on the result, particularly if it be long delayed, or accompanied by much suppuration.

The time at which return of sensation takes place is very variable, in some cases sensibility being well marked in a few days, in others not until months or even years have elapsed. It is sometimes noticed, as in my musculo-spiral case, that, very soon after suture, a painful sensation pervades all the branches of distribution of the severed nerve, and this is sometimes the precursor of a healthy restoration of sensibility. It is not so always, however, but sometimes gradually subsides, leaving the parts in their original, more or less, perfect insensitiveness. The return of motility is commonly longer delayed than the return of sensibility. Here we have not only the degeneration of the nerve, but degeneration of muscular fiber

to be overcome, and, accordingly, this paralysis is not only more slowly recovered from, but much more frequently remains a permanent disablement. It will be noticed that, in this communication, I have scarcely alluded to the trophic changes, which are so certain to ensue after nerve-section. This has not been because I undervalued these changes, either in their clinical or scientific aspects. It is simply because in the two cases, which have been the basis of my studies, these trophic changes never assumed any prominence.

With regard to the results of the operations that have been put on record, the most recent and best tabular statement is found in Weissenstein's article on Secondary Nerve Suture, in von Bruns's "Chirurgische Klinik," 1884. He gives the results of thirty-three cases, from all sources, in which the operation has been done at varying periods after the nerve injury, in almost every case after the original wound had healed. To these thirty-three cases I have been able to add the following:

1. *Dr. W. S. Halsted's case.* — B., aged twenty-two years, injured by glass. Degenerative reaction of muscles and complete loss of sensation in the regions supplied by the median and ulnar nerves at the time of the eighth month after the injury. Separation after paring off nerve-ends, about three inches. Neuro-plastic suture of median and direct suture of the ulnar, with relaxation sutures in both. Strong flexion of hand and forearm, and still some tension. The wound healed by primary union. No benefit six months after the operation.

2. *By Dr. Weir.*—Wound of sciatic nerve nine years previously, operated on December, 1882; catgut sutures. By suturing adjacent tissues, and flexing knee forcibly, approximation was obtained. No improvement in motility, but gain in general sensation, and great improvement in trophic changes, which had advanced to ulceration. The ulcers all healed and local nutrition generally improved.

3. *A case operated on by Dr. W. T. Bull in July, 1883.*— It was a case of wound of median and ulnar nerves with corresponding paralysis. The suture of both nerves with catgut was done about seven weeks after injury. Was discharged from the hospital about five weeks after operation, with both sensation and motility beginning to return, and improving daily.

4. *A case reported by Dr. Roswell Park, of Chicago*, in which the radial was sutured with catgut sixteen days after its division. The recovery was rapid, the patient being considered well in six weeks.

5. *The case reported by me above*, of musculo-spiral suture forty-six days after wound. Catgut suture, recovery of sensation and motion, with a useful limb; daily improving.

6. *The case reported above* of suture of upper cord of brachial plexus, one hundred and thirty-one days after its division. Recovery of sensation and motion, and nutritive condition daily becoming more perfect.

Müller adds two cases, and Tillaux also two cases, making the whole number of secondary sutures reported forty-three.

These ten cases, added to Weissenstein's thirty-three, make in all forty-three cases. Of these, thirty-three were successes, in so far that sensibility and motility were at least partly recovered. In six cases no improvement, or almost none, occurred, and in four cases the data were insufficient for statistical use. The dates of improvement can be given approximately thus: Traces of sensibility were noted in from two to four weeks. Traces of motility in from sixteen days to sixty; in two cases more than a year. Complete restoration of muscle function was marked in one case as occurring in twenty-six days; in several cases not till the lapse of one or even more years. All the authors seem to agree that electricity and massage greatly favored the return of function in the paralyzed parts. If now we consider that three-quarters of all the reported cases were more or less successful, and still further consider that many of the cases were reported so soon after operation that the full results had not yet been realized, I think we are warranted in concluding that the proceeding promises a degree of success which we can count upon in very few of the operations which we are every day performing. When we take into account the serious and permanent disability for the cure of which the operation is recommended, the entire freedom from danger to life, no fatal case having been reported, and the large measure of success which has followed its performance, we are entitled, I think, to regard it as one of the best and most useful contributions that have been made to modern surgery.